AMRITA VISHWA VIDYAPEETHAM

PROGRAM
MD NUCLEAR MEDICINE

(Revised with effect from 2014-2015 onwards)

Contents

Program Outcomes

PO1: Knowledge of basic principles of radiation physics and its subsequent applications, necessary in the practice of the subject.
PO2: Knowledge of radiation protection principles, necessary for safe practice of the subject.
PO3: Expertise in safe handling of radionuclides and their disposal.
PO4: Knowledge of International Commission for Radiological Protection (ICRP) and National Regulatory guidelines pertaining to nuclear medicine practice.
PO5: Knowledge of diagnostic tests, interpretation of results and pitfalls.
PO6: Competence in good clinical practice of therapeutic nuclear medicine and dosimetry.

Program Specific Outcomes

PSO1: Skill in practical aspectss related to Physics, Instrumentation and its quality Control.
PSO2: Skill in preparation of radiopharmaceuticals and their quality control.
PSO3: Skill in detection of contamination in various workplaces.
PSO4: Skill in characterization of unknown isotopes.
PSO5: Skill in management of accidental spillage.
PSO6: Skill in GFR Estimation.
PSO7: Skill in the clinical experiment of osophageal transit time.
PSO8: Skill in the clinical experiment of gastric emptying time.
PSO9: Skill in the clinical experiment of renal transplant evaluation
PSO10:Skill in the clinical experiment of determination of Ejection Fraction and RWMA (wall motion).

CORE SUBJECTS

1. **Basic Mathematics.**
   - **a)** Logarithmic & exponential functions
   - **b)** Differentiation & integration
   - **c)** Simple first & second order differential equations & their solutions.
   - **d)** Compartmental analysis.

2. **Basic medical statistics**
   - **a)** Mean, Mode, Median
   - **b)** Standard deviation percent standard error - standard error of Mean (SEM)
   - **c)** Binomial, Poisson & Gaussian distribution, Estimations & confidence limits.
   - **d)** Null hypothesis & significance tests (students test etc)
   - **e)** Analysis of variation & covariation, correlation coefficient by curve fitting method of least square fit.
   - **f)** Computer methods of analyzing medical data.

3. **Fundamentals of electricity & electronics**
   - **a)** Electrical conductivity, charge, voltage, current & resistance, Coulomb's law, Ohm's law, D.C. & A.C.

b) Components of electronic circuits, active & passive elements : their function & applications.
c) Basic electronic circuits : power supply, amplifiers, oscillators, pulse shapers.
d) Introduction to digital electronics : ADC, DAC, logic units, integrated, circuits,
e) microprocessors.

4. Basic principles of Immunology :

a) Introduction :- Antigen – antibody reaction – basis of specificity.
b) Immunoglobulins : Structure of immunoglobulins – variations in structure of immunoglobulins – comparison of immunoglobulin classes.
c) Synthesis of antibody :
- Types of immune response :
- Role of lymphocytes & details about the immune response & functions – Two populations of Lymphocytes : T & B – cells.
- Cellular co-operation in the immune response synthesis of humoral antibody
- Immunological tolerance
- Theories of antibody synthesis.

d) "In vitro " Immune reactions
e) Precipitation – Antigen binding techniques – Immunofluorescence
f) Reactions with cell surface antigens complement – Neutralization of biological activity – Lymphocyte stimulation – Leucocyte migration inhibition test.
g) Hypersensitivity : Types of hypersensitive reactions, Autoimmunity.

5. Basic principles of chemical reactions

- Fundamental concepts, oxidation, reduction, acids, bases, hydrogen, Ion concentration, dissociation constants, pH value, Ionic equilibria, buffer solutions.
- Fundamental concepts of organic chemistry, hydrocarbons, aliphatic hydroxyl compounds, non aliphatic hydroxy compounds, aldehydes, ketones, carboxylic acids, esters amines, amides hydrogen derivatives.
- Chemical bonds – electrovalent bond, covalent bond & co-ordinate covalent bond. Chelate compounds.

6. **Elements of anatomy & physiology** of different body organs considered in scintigraphy & other nuclear medicine investigations.

7. Nuclear Medicine Instruments

Block diagram & understanding of specifications of the following instruments, power supply, voltage regulators, count rate meter, oscilloscope display, video display, chart recorder, printers.

8. <u>Instrument maintenance</u>

General care & maintenance of the electronic equipment in nuclear medicine laboratory.

MAIN SUBJECTS:

1. **RADIATION BIOLOGY**

a) Brief overview of interactions of ionizing radiation with matter.

b) Sources of Radiation

- Environmental - Natural , Manmade
- Medical
- Occupational

c) Measurement of Radiation and its Effects

- Exposure
- Absorbed dose
- Dose equivalent

d) Review of Cell Biology –

1. Cell structure, Molecular components,Cell reproduction
    - DNA synthesis
    - Mitosis
    - Meiosis
2. Cell replication cycle
3. Chemical effects of radiation.
4. Radiation effects on Macromolecules.
5. Cell survival curves.
6. LD 50 effects.
7. Concepts of Clinical radiation pathology.
8. Relative biological effectiveness (RBE)
9. Free radicals
10. Target theory
11. Radiation Genetics

A. Causes and effects of genetic mutations

1. Spontaneous mutation
2. Mutagenesis
3. Carcinogenesis
4. Gene mutations and cancer

B. Effects of radiation on DNA

C. Chromosome and chromatid aberrations

D. Repair versus mutation

e) Cellular Responses to Radiation

A. Stage of cell replication cycle versus radiosensitivity

Factors Affecting Cellular Response to Radiation

RBE and $LD_{50/30}$

Physical factors

Chemical factors
Biological factors

f) Radiosensitivity and Cell Populations . Law of Bergonie and Tribondeau
g) Tissue and Systemic Responses to Radiation
A. Acute versus late effects
B. Healing of irradiated tissue
C. Total-body irradiation
1. Sources of information
2. Hematopoietic syndrome
3. Gastrointestinal syndrome
4. Central nervous system syndrome
5. Cardiac shock syndrome

A. Radiosensitivity of embryo/fetus
B. Phases of embryonic/fetal development
C. Effects of radiation versus phase of development

h) Late Effects of Radiation Exposure
A. Relating radiation exposure to specific effects
1. Dose versus effect models
2. Problems associated with researching radiation-induced effects/disease
Non-specific life-shortening
Genetic effects (spontaneous mutation versus radiation induced damage)
Carcinogenesis
Cataract instigation
Other diseases

i) Radiation doses
A. Factors influencing absorbed dose from internal sources
1. Concentration and organ mass
2. Effective half-life
3. Physical and chemical characteristics of radionuclide
4. Absorbed fraction
5. Cross-irradiation
B. Critical and target organs
1. Target organs
2. Non-target critical organs
3. Gonadal exposure
C. Absorbed dose calculations
1. Classical and MIRD methods
2. Formulas
3. Charts and tables

j) Risk-to-Benefit Ratios
A. Radiation hazard versus medical need
B. Diagnostic exposures

1. Exposure from various sources (x-ray, computed tomography, etc.)
2. Radiation levels in nuclear medicine

C. Therapeutic exposures

1. Exposure from various sources (radiation therapy, implants, etc.)
2. Radiation levels in nuclear medicine

NUCLEAR PHYSICS

1. **Structure of atom** : Different models of atom, Physical & chemical properties. Avogadro's Number, Periodic table, isotopes, isobars & isotones.
2. **Radioactivity** : Nuclear forces, nature & origin of radioactivity, types of radiations, nuclear transitions, units of radioactivity, physical properties of radioactivity, radioactive decay, decay schemes, trilinear radionuclide chart, physical half life, decay constant, average life, biological & effective half life, radionuclides in equilibrium, natural & artificial radioactivity.
3. **Production of radioisotopes** :- Fission process, nuclear reactions, nuclear reactors, accelerators, medical cyclotrons, nature & properties of artificially produced radioisotopes.
4. **Interaction of radiation with matter** :

- Interaction of alpha & beta particles with matter, scatter, ionization, bremhstrahlung, cerenkov, annihilation reactions.
- Interaction of gamma radiation with matter : scatter, photoelectric effect, pair production
- Penetration of radiation in matter, half value thickness, absorption coefficient, absorption cross section curves with respect to gamma energy & atomic number. Range of radiations in tissue, lead & NaI (T1)

Radiation detection & measurement

1. Radiation detectors (gas) : Ionization chamber, proportional counters, GM counter – principles, operation & use in nuclear medicine.
2. Scintillation detectors (solid) : NaI (T1), CsI, BGO, LSO crystals, photomultiplier tube.
3. Scintillation detectors (Liquid) : Liquid organic scintillators sample preparation, quenching & its correction.
4. Semiconductor detectors : Principle, properties & use
5. Gamma ray spectrometer : Principle, operation & use.
6. Measurement of radioactivity : Principles, counting geometry, efficience of detection in in-vitro 'in-vivo' counting.
7. Counting statistics : Standard deviation (SD) \, percent error measurement of SD of addition, substraction, multiplication & division of two countrates.

Health Physics :

1. Units & definitions : Radiation, exposure, absorbed dose in air & in man, SI units.
2. Radiation Exposure : Natural radioactivity in man, exposure from natural & artificial sources, concept of maximum permissible level, ICRP regulations, exposures in pregnancy, in children & in radiation laboratories.
3. Radiation protection : Evaluation of radiation hazards, protection measures, shielding personal & area monitoring, internal radiation hazards, control of contamination waste disposal, permissible levels, techniques of licensing.
4. Radiation Measuring instruments : GM counters, contamination monitors, exposure monitors – film badge, TLD, gun monitors, dosimeters. Dose calibrators & quality control of dose calibrators.
5. Internal radiation dosimetry : Estimation of radiation dose delivered to various body organs & total body by internally administered radionuclides for diagnostic & therapeutic purposes by MIRD methods.

Scintigraphy (Instrumentation)

1. Rectilinear scanners : Instrument & principle of working, collimators & their evaluation, technique of scanning on a scanner, limitations & pitfalls concept of information density in imaging, various types of scanners.
2. Scintillation cameras : Description of instrument and principle of working collimators & their evaluation, technique of organ imaging on a scintillation camera, limitations & pitfalls, how to choose a scintillation camera.
3. Other imaging devices (emission type) : Positron emission tomography system, Freshnel zone plate camera, semiconductor camera, multiwire proportional counter camera.
4. Tomography : Concept of tomography in imaging, emission tomographic cameras.
5. Photographic processes : Display systems in nuclear medicine imaging, hard copy records, concepts of exposure & developing of a transparency film, preparation of dark room & developing solutions, film characteristics and its importance in imaging.
6. Quality assurance & quality control of nuclear medicine imaging instruments scanners & scintillation cameras : methods of quality control, guidelines for daily & periodic tests.

Other imaging modalities

1. Computerised Tomography
2. Ultrasonic imaging.
3. N M R Imaging.

DYNAMIC STUDIES IN NUCLEAR MEDICINE

1. Instrumentation : Clinical analyzer, computers description & principle of working of the computer. Technique of performing dynamic studies with computer, Limitations & pitfalls.
2. Nuclear Cardiology : Radiopharmaceuticals, first pass & multigated equilibrium studies, determination of cardiac shunts, ejection fractions at rest & in stress, coronary blood flow

studies – wall motion studies, newer developments in nuclear cardiology techniques,. Clinical evaluation of the nuclear cardiology techniques, its merits.

3. Renal studies : Radiopharmaceuticals, measurement of renal blood flow, glomerular filtration rate, renal clearance & rejection of grafting in renal transplant by radionuclide renal studies, merits & demerits.
4. Dynamic studies using PET RP: Cerebral & cardiac reserve.

RADIOPHARMACEUTICALS :

1. General principles of tracer techniques.
2. Production of Radionuclides – SPECT & PET.
3. Reactor & its principle
4. Production of radionuclides in reactor
5. Cyclotron & its principle
6. Different generator systems
7. Production of radionuclides in cyclotron.
8. Linear accelerator
9. Betatron
10. Choice of radionuclides
11. Primary radionuclides – labeled compounds, Iodination, labeling with other radionuclides.
12. Therapeutic radionuclides
13. Purity of radiopharmaceuticals.
14. Chemical purity, Radiochemical purity, Radionuclide purity, Biological purity.
15. Stability of radiopharmaceuticals, parameters which affect stability
16. Quality control of radiopharmaceuticals
17. Radiochemical & chemical purity – methods used to determine.
18. Radionuclidic purity – methods used.
19. Sterility testing – methods used.
20. Pyrogen testing – methods used.
21. Various types of radionuclides generators
22. ^{99} Mo -^{99m}Tc generator & preparation of different labeled compounds with Tc 99m.
23. ^{113}Sn - ^{113m} In generator & preparation of different labeled compounds.
24. ^{68}Ge – ^{68} Ga generator & preparation of different labeled compounds.
25. Other generators of interest in Nuclear Medicine.
26. Mechanism of localization of radiopharmaceuticals – modern trends in radiopharmaceuticals.
27. Handling of radiopharmaceuticals.
28. Safety measures, equipments, shields, remote handling etc.
29. Dose preparation, packaging, storage, waste disposal
30. Economic aspects of radiopharmaceuticals
31. Legal aspects of radiopharmaceuticals.

CLINICAL SCINTIGRAPHY :

1. Brief review of anatomy of organ

2. Brief review of physiology
3. Radiopharmaceuticals used for imaging the organ & merits or demerits if any
4. Methods of localization of radiopharmaceuticals
5. Difference in SPECT & PET techniques, advantages , disadvantages
6. Use of SPECT CT & PET CT
7. PET MR imaging
8. Normal scan appearances in planar, SPECT & PET – normal physiological & anatomical variations
9. Artifacts in scan interpretations
10. Abnormal scans with respect to clinical diagnostics
11. Procedures of all planar, SPECT & PET scans
12. Indications & usefulness of scan with respect to clinical diagnosis
13. Limitations of information obtained by scans
14. Newer modalities of imaging like ultrasound, CT, NMR & comparison with nuclear medicine techniques.

THYROID FUNCTION STUDIES

1. Physiology of thyroid gland – Iodine metabolism in man
2. In vivo thyroid function tests : Thyroid uptake, PB 131 T, T3 supression, TSH stimulation, perchlorate discharge test, Techniques of performing these tests, their limitations.
3. In vivo thyroid function tests : PB I, T3 –charcoal ratio, T3 – RBC uptake, competitive protein binding assays for T3, T4, free T4 & FTR, merits & demerits, factors affecting these tests.

THERAPEUTIC APPLICATIONS OF RADIONUCLIDES :

1. Treatment of hyperthyroidism with radioiodine,
2. Treatment of thyroid cancer,
3. Bone pain palliation
4. Therapy for polycythaemia vera
5. Radiosynovectomy
6. Monoclonal antibodies treatment
7. Other modes of internally administered isotopes for therapy.

Absorption studies :

1. Whole body counters : Instrument description, principle of working & technique of whole body counting, different types of whole body counters, their merits & demerits.
2. Basic principles of absorption studies, factors affecting absorption, clinical evaluation of these studies B-12 absorption studies, shielding test, double tracer technique, iron absorption, folic acid absorption, T3-T4 absorption – Dual marker technique.

Haematological uses of radioisotopes

Blood volume, RBC volume, plasma volume, RBC survival etc.

In vitro techniques :

1. Tracer kinetics : Principle of single compartment – multi compartment basic equations.
2. Body fluids & electrolytes : turnover of total body sodium, potassium etc.Total body water – Body composition of various electrolytes.
3. Erythrokinetics – Iron kinetics, clinical usefulness, medullary & extra medullary erythropoiesis etc
4. Protein turnover studies – synthesis & catabolism – use of radioactive tracers in albumin turnover.
5. Radiorespirometry : Glucose, palmatic acid & carbohydrate metabolism use of technique for bacterial contamination, drug sensitivity etc
6. Neutron activation analysis – detection of tracer elements in biological samples.
7. Autoradiography
8. Biochemical applications of tracers
   Carbohydrate (Chemistry, metabolism)
   Lipids ((Chemistry, metabolism)
   Proteins (Chemistry, metabolism)
   Nucleic acids
   Vitamins, Minerals & Enzymes

RADIOIMMUNOASSAYS :

1. Principles of RIA. General considerations in the preparation of iodine labeled tracers.
2. Selection of suitable radioisotope, Radioactive labeling of proteins.
3. Mechanism of Iodination & structure of Iodinated compounds.
4. Methods of iodination, Specific activity & substitution levels.
5. Iodination damage & quality control of iodinated tracers.
6. Stability of iodinated tracers.
7. Radioiodination & safety measures
8. Definition of antibodies, their function & mode of preparation.
9. Specificity of antibodies. Properties of antibodies. Affinity & binding capacity. Quality control of antibodies. Other variants of binding substances. Assay procedure & optimization of assay procedures. Separation methods of bound and free fractions. Data processing & computations.
10. Quality control measures in RIA's.

Receptor assays : Receptors, their physiological role mechanism of action & utility inn clinical diagnosis.

Enzyme immunoassay – Principles & applications in clinical diagnosis

Administrative aspects of Nuclear Medicine :

1. Planning of radioisotope laboratory : Basic considerations, layout, equipment, classification of Nuclear Medicine laboratory, staff, clearance of premises, licensing for use of radionuclides in humans.
2. Cost benefit & efficacy of Nuclear Medicine investigations, role of Nuclear Medicine in diagnostic decision making, professional ethics.
3. Layout & commissioning of High dose RN Therapy wards
4. Layout & commissioning of PET CT

PRACTICALS SYLLABUS:

RADIOPHARMACY PRACTICALS

1. (a) Familiarisation with measurement of radioactivity using a dose calibrator.
   (b) K Factor for different radionuclides.
   (c) Determination of t 1/2 of short / intermediate / comparatively longer-lived RP
   (d) Theoretical concepts, Physics of instrumentation.

2. (a) Familiarisation with the handling of radioactivity – low & high level – safety practices, protection – wearing safety apparel.
   (b) Handling of radioactive sources – sealed / unsealed, remote handling equipment – tongs / forceps / shielded devices.
   (c) Actual handling of radioactive solutions in glass apparatus, both dummy & under real conditions
   of work up.
   (d) Concept of contamination, measurement, decontamination.
   (e) Theoretical aspects – health physics & radiation protection principles.

3. (a) Familiarisation with pharmacy practices – sterility, apyrogenicity, aseptic transfers, intravenous
   injections, clean environment, safeguards.
   (b) Withdrawal of injectable solutions, dispending – same with radioactive solutions, micro-filtration, dose formulation with radioactive solutions.
   (c) Theoretical concepts – Pharmacy practices employed in preparation of pharmaceuticals
   (to be read).

4. (a) Familiarisation with radiochemistry practices, separations techniques –
   Solvent extraction / column chromatographic method of separation of 99m TcO4 – from
   99MoO.

5. (a) Solvent extraction system – design of the system. Purification of 99m TcO4, injectable
   formulation of ^{99m}Tc – Radiopharmaceiticals. (The candidate is expected to familiarize

himself with the process & to perform the exercise at least 4 to 6 times under supervision).

(b) Cross- Contamination, Avoidance.

(c) Theoretical aspects to be studied.

6. Concepts of Quality assurance & control
   (a) Radionuclidic / radiochemical/ biological etc
   (b) Principles as applied to 99 m Tc-radiopharmaceuticals – absence of 99Mo, biodistribution, chromatography.

7. Preparation of 'kits' – types, dosage forms, 99m Tc-radiopharmaceuticals – Characteristics.
   (a) Criteria of integrity, lyophilized & other forms.
   (b) Theroretical principles (to be read).

8. Paper chromatography of ^{99m}TcO4 in physiological saline
   (a) Counting procedures. (in general)
   (b) Rf value
   (c) Theoretical principles (to be read)

9. Paper chromatography of a few of the following injectables
   (a) Preparations, e.g. ^{99m} Tc-MDP/ ^{99m} Tc-DTPA/^{99m}Tc-S.Colloid / ^{99m} Tc-Phytate.
   (b) Concept of purity. Inadequacies of the system. Alternate / complementary methods.

10. Trouble – shooting
   (a) Paper chromatography of designated ^{99m} Tc-radipharmaceuticals formulated from 'kits' of doubtful integrity, e.g. ^{99m} Tc-MDP
   (b) Comparison of results.
   (c) Theoretical principles
   (d) Radionuclidic impurities estimation-

   All other radionuclide impurities : Not more than 0.1 mCi of all other B Emitters for mCi of 99m Tc at time od administration <0.001 mCi of gross & impurity / mCi of 99mTc at time of administration.
   Pyrogen, sterlity requirements.
   Chemical purity

<u>PHYSICS PRATICALS:</u>

1. Charateristics of different radiations,
2. Absorption & back scatter of radiation,
3. Plateau of G.M.Counter,
4. Half valve layer,
5. Half life
6. Resolution of half lives from a mixture of radionuclides,
7. Daughter-parent relationship in radioactive decay and radionuclides,
8. Efficiency of counting,

9. Counting statistics,
10. Gamma gray spectrometry,
11. Identification of an unknown radionuclide,
12. Isoresponse curve of different collimators.
13. Lines spread function,
14. Liquid scintillation counting counting.
15. Autoradiography.
16. In vitro radiorespirometry.
17. Radiation exposure : effect of distance
18. Shieliding
19. Radiation survey.
20. Decontamination
21. Radiopharmacy procedures & elution of generators, preparation of different radio pharamacuticils.
22. Orcy soale calibaration. (Calibaration of a photo scanner)
23. Phantom studies for scintigraphy,
24. Flood field for scintigraphy.
25. Organ imaging.
26. Photographic development.
27. Profile scanning.
28. Analog studies with single or multiple probes,
29. Dilution principle,
30. In vitro sample measurement of various types,
31. Flow measurements
32. Renogram
33. Thyroid uptake
34. Radioimmunoassays of various types.

COURSES

Course - I Basic Science (Code MDNM1)

CO1: Knowledge of radiation physics and instrumentation.
CO2: Knowledge of mathematics, statistics and computer sciences.
CO3: Knowledge of the biological effects of radiation exposure with emphasis on the effects of low level exposure. Knowledge of the methods of reducing unnecessary radiation to patients, personnel and environment.
CO4: Knowledge of the ICRP recommendations and their amendments from time to time and other international recommendations, environmental regulations, handling of radioactive patients, transport of radioactive material and disposal of radioactive wastes.
CO5: The diagnosis, evaluation and treatment of radiation over exposure in any form.

RADIATION BIOLOGY

Brief overview of interactions of ionizing radiation with matter.

Sources of Radiation

- Environmental - Natural , Manmade

- Medical
- Occupational

Measurement of Radiation and its Effects

- Exposure
- Absorbed dose
- Dose equivalent
- Radiation and its effect on cell cycle
- Tissue specific maximum dose of radiation

Review of Cell Biology –

Cell structure, Molecular components,Cell reproduction

- DNA synthesis
- Mitosis
- Meiosis

Cell replication cycle
Chemical effects of radiation.
Radiation effects on Macromolecules.
Cell survival curves.
LD 50 effects.
Concepts of Clinical radiation pathology.
Relative biological effectiveness (RBE)
Free radicals
Target theory
Concept of Brachytherapy
Radiation Genetics

A. Causes and effects of genetic mutations
    1. Spontaneous mutation
    2. Mutagenesis
    3. Carcinogenesis
    4. Gene mutations and cancer
B. Effects of radiation on DNA
C. Chromosome and chromatid aberrations
D. Repair versus mutation

Cellular Responses to Radiation

A. Stage of cell replication cycle versus radiosensitivity

Factors Affecting Cellular Response to Radiation

RBE and $LD_{50/30}$
Physical factors
Chemical factors
Biological factors

Radiosensitivity and Cell Populations . Law of Bergonie and Tribondeau
Tissue and Systemic Responses to Radiation

A. Acute versus late effects
B. Healing of irradiated tissue
C. Total-body irradiation
1. Sources of information
2. Hematopoietic syndrome
3. Gastrointestinal syndrome
4. Central nervous system syndrome
5. Cardiac shock syndrome

A. Radiosensitivity of embryo/fetus
B. Phases of embryonic/fetal development
C. Effects of radiation versus phase of development

Late Effects of Radiation Exposure
A. Relating radiation exposure to specific effects
1. Dose versus effect models
2. Problems associated with researching radiation-induced effects/disease
Non-specific life-shortening
Genetic effects (spontaneous mutation versus radiation induced damage)
Carcinogenesis
Cataract instigation
Other diseases

Radiation doses
A. Factors influencing absorbed dose from internal sources
1. Concentration and organ mass
2. Effective half-life
3. Physical and chemical characteristics of radionuclide
4. Absorbed fraction
5. Cross-irradiation
B. Critical and target organs
1. Target organs
2. Non-target critical organs
3. Gonadal exposure
C. Absorbed dose calculations
1. Classical and MIRD methods
2. Formulas
3. Charts and tables

Risk-to-Benefit Ratios
A. Radiation hazard versus medical need
B. Diagnostic exposures
1. Exposure from various sources (x-ray, computed tomography, etc.)
2. Radiation levels in nuclear medicine
C. Therapeutic exposures
1. Exposure from various sources (radiation therapy, implants, etc.)
2. Radiation levels in nuclear medicine

NUCLEAR PHYSICS

Structure of atom : Different models of atom, Physical & chemical properties. Avogadro's Number, Periodic table, isotopes, isobars & isotones.
Radioactivity : Nuclear forces, nature & origin of radioactivity, types of radiations, nuclear transitions, units of radioactivity, physical properties of radioactivity, radioactive decay, decay schemes, trilinear radionuclide chart, physical half life, decay constant, average life, biological & effective half life, radionuclides in equilibrium, natural & artificial radioactivity.
Production of radioisotopes :- Fission process, nuclear reactions, nuclear reactors, accelerators, medical cyclotrons, nature & properties of artificially produced radioisotopes.
Interaction of radiation with matter :

- Interaction of alpha & beta particles with matter, scatter, ionization, bremhstrahlung, cerenkov, annihilation reactions.
- Interaction of gamma radiation with matter : scatter, photoelectric effect, pair production
- Penetration of radiation in matter, half value thickness, absorption coefficient, absorption cross section curves with respect to gamma energy & atomic number. Range of radiations in tissue, lead & NaI (T1)

Radiation detection & measurement

Radiation detectors (gas) : Ionization chamber, proportional counters, GM counter – principles, operation & use in nuclear medicine.
Scintillation detectors (solid) : NaI (T1), CsI, BGO, LSO crystals, photomultiplier tube.
Scintillation detectors (Liquid) : Liquid organic scintillators sample preparation, quenching & its correction.
Semiconductor detectors : Principle, properties & use
Gamma ray spectrometer : Principle, operation & use.
Measurement of radioactivity : Principles, counting geometry, efficience of detection in in-vitro 'in-vivo' counting.
Counting statistics : Standard deviation (SD) \, percent error measurement of SD of addition, substraction, multiplication & division of two countrates.

Health Physics :

Units & definitions : Radiation, exposure, absorbed dose in air & in man, SI units.
Radiation Exposure : Natural radioactivity in man, exposure from natural & artificial sources, concept of maximum permissible level, ICRP regulations, exposures in pregnancy, in children & in radiation laboratories.
Radiation protection : Evaluation of radiation hazards, protection measures, shielding personal & area monitoring, internal radiation hazards, control of contamination waste disposal, permissible levels, techniques of licensing.

Radiation Measuring instruments : GM counters, contamination monitors, exposure monitors – film badge, TLD, gun monitors, dosimeters. Dose calibrators & quality control of dose calibrators.
Internal radiation dosimetry : Estimation of radiation dose delivered to various body organs & total body by internally administered radionuclides for diagnostic & therapeutic purposes by MIRD methods.

Course - II Clinical Nuclear Medicine I (MDNM2)

CO1: Knowledge of radiopharmaceuticals.
CO2: Skill in in vivo diagnostic imaging.
CO3: Competence in in vitro studies.

RADIOPHARMACEUTICALS :

1. **General principles of tracer techniques.**
2. Production of Radionuclides – SPECT & PET.
3. Reactor & its principle
4. Production of radionuclides in reactor
5. Cyclotron & its principle
6. Different generator systems
7. Production of radionuclides in cyclotron.
8. Linear accelerator
9. Betatron
10. **Choice of radionuclides**
11. Primary radionuclides – labeled compounds, Iodination, labeling with other radionuclides.
12. Therapeutic radionuclides
13. Purity of radiopharmaceuticals.
14. Chemical purity, Radiochemical purity, Radionuclide purity, Biological purity.
15. Stability of radiopharmaceuticals, parameters which affect stability
16. Quality control of radiopharmaceuticals
17. Radiochemical & chemical purity – methods used to determine.
18. Radionuclidic purity – methods used.
19. Sterility testing – methods used.
20. Pyrogen testing – methods used.
21. Various types of radionuclides generators
22. ^{99} Mo - ^{99m} Tc generator & preparation of different labeled compounds with Tc 99m.
23. ^{113}Sn - ^{113m} In generator & preparation of different labeled compounds.
24. ^{68}Ge – ^{68} Ga generator & preparation of different labeled compounds.
25. Other generators of interest in Nuclear Medicine.
26. **Mechanism of localization of radiopharmaceuticals – modern trends in radiopharmaceuticals**.
27. Handling of radiopharmaceuticals.
28. Safety measures, equipments, shields, remote handling etc.
29. Dose preparation, packaging, storage, waste disposal
30. Economic aspects of radiopharmaceuticals

31. Legal aspects of radiopharmaceuticals.

Course - III Clinical Nuclear medicine II (MDNM3)

CO1: Knowledge of the principles of internal dosimetry.
CO2: Awareness about the characteristics of radionuclides/radiopharmaceuticals for radionuclide therapy.
CO3: Competence in radiation protection in therapeutic set up.
CO4: Knowledge of the principles of OPD and in-door therapy administration.
CO5: Skill in therapy in thyroid disorders.
CO6: Competence in bone pain palliation.
CO7: Skill in radiosynevectomy, radiopeptide therapy, radioconjugate therapy, radioimmunotherapy and locoregional internal radiation therapy.
CO8: Familiarity with research agents in radionuclide therapy.

CLINICAL SCINTIGRAPHY :

15. Brief review of anatomy of organ
16. Brief review of physiology
17. Radiopharmaceuticals used for imaging the organ & merits or demerits if any
18. Methods of localization of radiopharmaceuticals
19. Difference in SPECT & PET techniques, advantages , disadvantages
20. Use of SPECT CT & PET CT
21. **PET MR imaging**
22. Normal scan appearances in planar, SPECT & PET – normal physiological & anatomical variations
23. Artifacts in scan interpretations
24. Abnormal scans with respect to clinical diagnostics
25. Procedures of all planar, SPECT & PET scans
26. Indications & usefulness of scan with respect to clinical diagnosis
27. Limitations of information obtained by scans
28. Newer modalities of imaging like ultrasound, CT, NMR & comparison with nuclear medicine techniques.

THYROID FUNCTION STUDIES

4. Physiology of thyroid gland – Iodine metabolism in man
5. In vivo thyroid function tests : Thyroid uptake, PB 131 T, T3 supression, TSH stimulation, perchlorate discharge test, Techniques of performing these tests, their limitations.
6. In vivo thyroid function tests : PB I, T3 –charcoal ratio, T3 – RBC uptake, competitive protein binding assays for T3, T4, free T4 & FTR, merits & demerits, factors affecting these tests.

THERAPEUTIC APPLICATIONS OF RADIONUCLIDES :

8. Treatment of hyperthyroidism with radioiodine,

9. Treatment of thyroid cancer,
10. Bone pain palliation
11. Therapy for polycythaemia vera
12. Radiosynovectomy
13. Monoclonal antibodies treatment
14. Other modes of internally administered isotopes for therapy.

Absorption studies :

3. Whole body counters : Instrument description, principle of working & technique of whole body counting, different types of whole body counters, their merits & demerits.
4. Basic principles of absorption studies, factors affecting absorption, clinical evaluation of these studies B-12 absorption studies, shielding test, double tracer technique, iron absorption, folic acid absorption, T3-T4 absorption – Dual marker technique.

Haematological uses of radioisotopes

Blood volume, RBC volume, plasma volume, RBC survival etc.

In vitro techniques :

9. Tracer kinetics : Principle of single compartment – multi compartment basic equations.
10. Body fluids & electrolytes : turnover of total body sodium, potassium etc.Total body water – Body composition of various electrolytes.
11. Erythrokinetics – Iron kinetics, clinical usefulness, medullary & extra medullary erythropoiesis etc
12. Protein turnover studies – synthesis & catabolism – use of radioactive tracers in albumin turnover.
13. Radiorespirometry : Glucose, palmatic acid & carbohydrate metabolism use of technique for bacterial contamination, drug sensitivity etc
14. Neutron activation analysis – detection of tracer elements in biological samples.
15. Autoradiography
16. Biochemical applications of tracers
    Carbohydrate (Chemistry, metabolism)
    Lipids ((Chemistry, metabolism)
    Proteins (Chemistry, metabolism)
    Nucleic acids
    Vitamins, Minerals & Enzymes

Course - IV Recent Advances (MDNM4)

CO1: Familiarity with recent advances in instrumentation
CO2: Familiarity with recent advances in radiopharmaceuticals.
CO3: Familiarity with recent advances in diagnostic procedures.
CO4: Familiarity with recent advances in radionuclide therapy.

Recent research activities and publications about the subject at the international level. Awareness about recent innovations and treatment methodologies adopted in our country and other countries

Course V Soft Skills (MDNM5)
Elective Course
CO1: The attitude to be a lifelong learner.
CO2: The competence to do a clinical research and write a thesis/dissertation under supervision.

CO3: The skill to communicate with patients, caregivers and colleagues, based on foundation of ethics, and etiquette.
CO4: Teaching skills.
CO5: The ability to be a leader/member of a healthcare team, develop an attitude of cooperation with colleagues, and interact with the patient and the clinician or other colleagues to provide the best possible diagnosis or opinion.

Amrita School of Medicine,
Amrita Institute of Medical Sciences,
Kochi, Kerala

Department of Nuclear Medicine & PET CT

LOGBOOK

MD IN NUCLEAR MEDICINE

Name of student :----------

Course duration: Month of --------- Year upto --------

Date of Enrolment: Month of --------- Year upto --------

Log book for the month of: --------- Year ---------

Total number of worked up cases :

WORKED UP CASES

CASE 1:

Name: Age/Sex: MRD:

CLINICAL INDICATION:

History

Examination

Salient Positive Findings

Scintigraphic Procedure

Scintigraphic Features

Other correlative Imaging details :

FOLLOW UP:

CASE 2:

Name: Age/Sex: MRD:

CLINICAL INDICATION:

History

Examination

Salient Positive Findings

Scintigraphic Procedure

Scintigraphic Features

Other correlative Imaging details :

FOLLOW UP:

Signature of Head
Department of Nuclear Medicine
Amrita Institute of Medical Sciences

REPORTING RECORD:

PLANAR INVESTIGATIONS:

PROCEDURES	NUMBER OF CASES
Technetium Thyroid Scintigraphy	
I-131 Wholebody Scintigraphy	

Tc MIBI Parathyroid Scintigraphy	
I-131 Thyroid Scintigraphy	
I-131 MIBG Imaging	
Liver colloid & Hepatobiliary Scintigraphy	
Tc- Salivary Scintigraphy	
Esophageal Transit Scintigraphy	
GE Reflux Scintigraphy (Milk scan)	
Tc RBC GI Bleed Scintigraphy	
Meckels Technetium Scintigraphy	
Tc RBC Blood pool Scintigraphy	
Motility Scintigraphy	
Whole body Skeletal Scintigraphy	
Sentinel scintigraphy	
Tc MIBI Whole body Onco Scintigraphy	
Lung Perfusion & Aerosol Ventilation Scintigraphy	
MUGA / RNV Scintigraphy	
Direct / Indirect Radionuclide MCU	
Testicular Scintigraphy	

SPECT & PET CT

SPECIAL INVESTIGATIONS	NO. OF CASES	IMPRESSION
MIBI Myocardial Perfusion Scan		
MIBI Parathyroid Scintigraphy		
Bone SPECT		
Liver SPECT		
Brain SPECT		

PET CT REPORTED	

PROCEDURES PERFORMED UNDER SUPERVISION

DATE	MRD	PROCEDURE	INDICATION	COMPLICATIONS	FOLLOW UP

LECTURES AND PRESENTATIONS

SRL NO	TYPE	DATE	TOPIC	PRESENTED/ATTENDED

1				
2				
3				
4				
5				
6				
7				
8				

SPECIAL INVESTIGATIONS

MODALITY	NUMBER OF CASES
SENTINEL IMAGING	
I-131 WHOLE BODY SCINTIGRAPHY	
LYMPHOSCINTIGRAPHY	
SCINTIMAMMOGRAPHY	
MUGA SCAN	

SPECIAL THERAPY PROCEDURES

PROCEDURES	NUMBER OF CASES
LOW DOSE I 131 THERAPY	
HIGH DOSE I-131 ABLATION	
HIGH DOSE I 131 METS THERAPY	
OTHERS	

DATE: SIGNATURE OF HEAD OF DEPARTMENT

Department of Nuclear Medicine
Amrita Institute of Medical Sciences

ANNEXURE V

QUARTERLY EVALUATION SHEET – PRACTICAL WORK

Name:

Date:

Sl.No.	Point to be considered	Score
1	Punctuality	
2	Regularity of attendance	
3	Quality of ward work	
4	Presentation of clinical cases	
5	Bedside manners	
6	Rapport with patients	
7	Rapport with colleagues	
8	Undergraduate teaching (if applicable)	
9	Physics & instrumentation	
10	Understanding the concept	
11	Demonstrating the procedure	
12	Analysis of result	
13	Record Maintenance	

Guidance for scoring:

0 *Poor*	*1* *Below average*	*2* *Average*	*3* *Above average*	*4* *Very good*

Total score ☐

ANNEXURE VI

6 MONTHLY EVALUATION SHEET – PRESENTATIONS/JOURNAL CLUB

FOR THE PERIOD ----------

Date:

Sl.No.	**Point to be considered**	Scoring
1	Clinical Presentations	
2	Whether all relevant points elicited	

3	Cogency of presentation	
4	Logical order	
5	Mentioned all positive and negative points of importance	
6	Whether any major signs missed or misinterpreted	
7	Diagnosis: whether it follows logically from history and findings	
10	Investigations required: - complete list - relevant order - interpretation of investigations	
Overall:		
1	Ability to react to questioning – whether answers relevant and complete	
2	Ability to defend diagnosis	
3	Ability to justify differential diagnosis	
4	Confidence	
5	Others	

Guidance for scoring:

0 *Poor*	*1* *Below average*	*2* *Average*	*3* *Above average*	*4* *Very good*

Total score: ☐

Sl.No.	Faculty Name
1	
2	
3	
4	

Date:

Sl.No.	**Point to be considered**	Scoring
1	Instrumentation Presentation	
2	Physics & instrumentation	
3	Understanding the concept	
4	Carrying out the procedure	
5	Analysis of result	
6	Record Maintenance	

Guidance for scoring:

0 *Poor*	*1* *Below average*	*2* *Average*	*3* *Above average*	*4* *Very good*

Total score:

Sl.No.	Faculty Name
1	
2	
3	
4	

Model Question Papers

Answer all questions in the given order
Total marks : 100, each question carries equal marks.
Time : 3 hrs

Paper I
1. Quality control of PET.
2. How will you maintain an optimal functioning of SPECT camera?
3. PET crystals.
4. Radiation monitoring instruments in nuclear medicine and the mechanisms on which they work.
5. Interaction of radiation with matter and their significance in nuclear medicine.
6. Phantoms and their uses.
7. a) N E C R
   b) 2D vs 3D PET acquisition
8. Radiation measurement quantities.
9. Attenuation correction
10. Common artefacts in SPECT and PET.

Paper II
1. Hereditary effects of radiation
2. How will you manage an accidental emergency in nuclear medicine department.
3. Regulatory aspects in setting up of a nuclear medicine laboratory.
4. Dose limits prescribed by ICRP and AERB.
5. Non-flourinated PET radiopharmaceuticals.
6. PET-based generators.
7. H. pylori breath test.

8. Differentiate radiochemical from radiopharmaceutical. Mechanisms of radiopharmaceutical uptake.
9. What are the types of equilibrium in relation to parent-daughter decay relationship?
10. How safe is nuclear medicine applications in children?

Paper III
1. Role of nuclear medicine in breast carcinoma?
2. Role of FDG-PET/CT in oncology
3. SPECT/CT in epilepsy.
4. Principles of radionuclide therapy
5. Compare RIA, ELISA and CLIA.
6. Myocardial viability studies.
7. Various physical and pharmacological stress agents in cardiac perfusion imaging.
8. Radiation synovectomy.
9. Significance of interventions in nuclear medicine. Enumerate them and describe one in detail.
10. Parathyroid localisation methods.

Paper IV
1. Role of nuclear medicine in opportunistic infections
2. Apoptosis imaging
3. Prostate imaging
4. Future clinical applications of PET
5. Latest developments of nuclear medicine imaging in neuroendocrine tumours management
6. Imaging of angiogenesis and hypoxia
7. Radioimmunoguided surgery. Its current status.
8. Coincidence detection systems. Its present day relevance.
9. Redifferentiation therapy and rh TSH in the management of thyroid cancer.
10. Imaging of dementia.